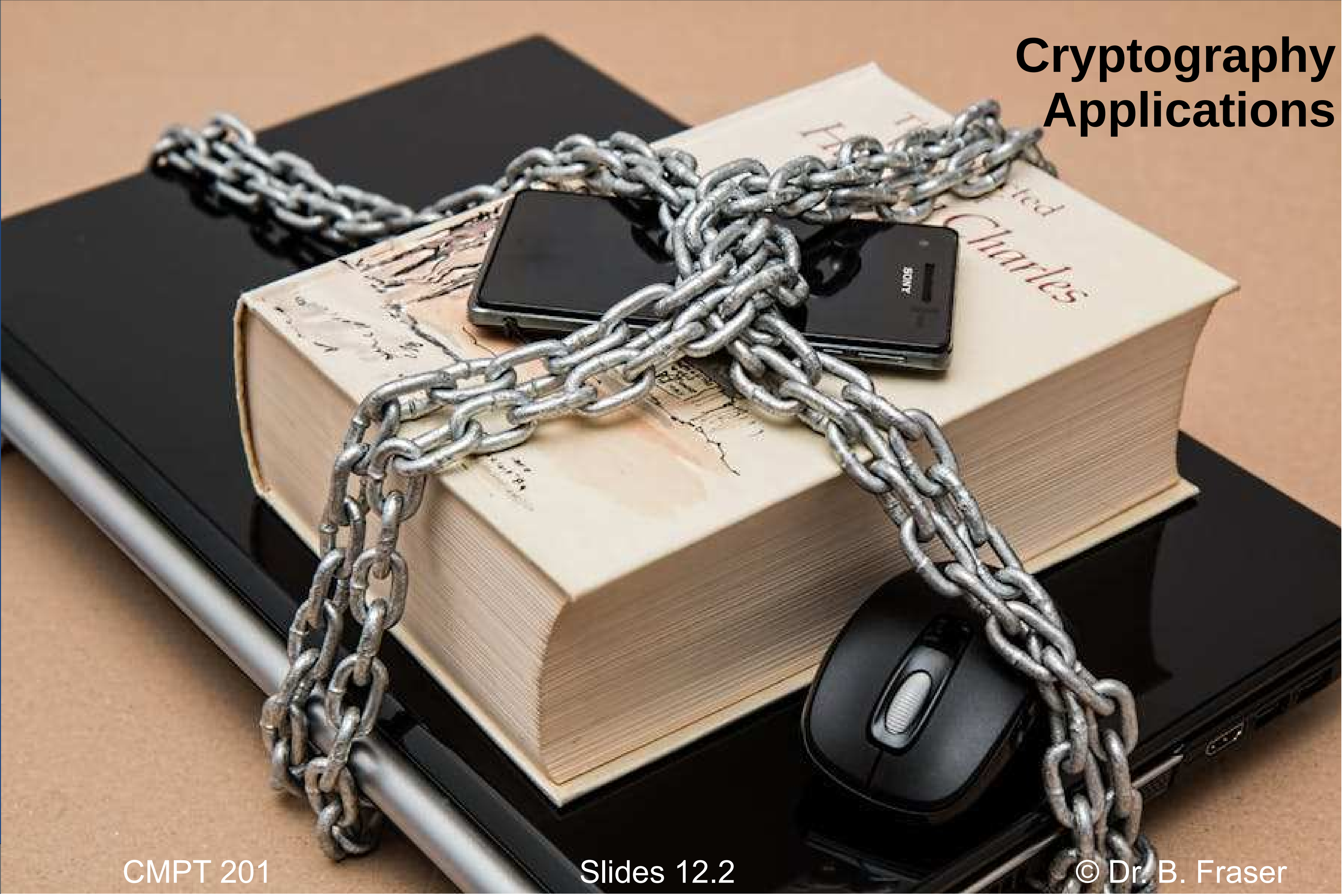
Cryptography Applications



CMPT 201 Slides 12.2

Topics

- How can we safely store passwords?
- How do we verify a document is authentic?
- How can we trust websites?

Storing Passwords

Storing Passwords

- Password verification systems don't store plain text passwords
  - ..
  - Adds security: attacker getting a copy of the password file gives them the hash which cannot be used to log in.
  - To check a password, system checks ..
- Linux stores passwords in /etc/shadow (accessible by root)

```
pwdis_1234:$y$j9T$LirzYIOxIHbbu6Wi/9zCI.$I9AZk5jAaY0uRPQfPnTEu.x5UeMVROrhP.i9gI96DD7:20159:0:99999:7:::
pwdis_1235:$y$j9T$Rnadt7C63/7BI1s/3Gx8v0$fvKI5ljHrj2hhnIhb6SkvjPvDQb7Awb3wUKU5YNmKK.:20159:0:99999:7:::
pwdis_abcd:$y$j9T$/TAaIyA61/IpbWM0vB5wA1$jofzhQHkwXjtpqfZ6cXIEwepD1L1V75gNriCM5C3pS7:20159:0:99999:7:::
```

User name

Hash alg. y=yescript

Salt

Hash

Password expiry info

Rainbow Table Attack

- Rainbow table attack
  - ..
  - Can then quickly search password file of hashes for known passwords.
- Defence: Salt the password.
  - Salt: ..
  - Store salt and hash(user-password || salt)
    (|| means concatenation)
  - Verify password:
    ..
- Attacker cannot reasonably compute hash of all possible passwords along with all possible salts.

Verifying Documents

Secure digest

- Secure digest for summary of document
  - Often used to verify a downloaded file is not corrupted.
  - A secure digest is a summary of a message:
    ..
  - Typically produced by a cryptographic hash function e.g., SHA-256.
- Example

```
$ sha256sum ./README.md
e293cdc4f5c4686772fba8159be9e9636654fed7ce72bfd2e75add8a6833c5ab  ./README.md
```

Digital Signature

- Digital signatures combine public key crypto and hashing.
  - Goal: ..
  - The message can be public;
    we just want to prove who sent it and that it's unaltered.
- Two parties: signer and verifier.
  - The Signer:
    - Sends a message
    - Wants to prove they sent the message.
  - The Verifier:
    - Receives message
    - Wants to verify the message was
      sent by the signer and is unaltered.

Signer

- The Signer will:
  - Writes a document: m
  - Computes a message digest: h(m) (e.g., using SHA-256)
    - Not good enough yet: Adversary could write document z, computes h(z) and plant both on the server.
  - ..
    (e.g., using RSA public key crypto)
    - This is called signing.
    - Only the signer has the private key,
      so only the signer can encode with it.
  - Sends the message & the signature:
    <m, enc(h(m))>

Verifier

- The Verifier will:
  - Receives the message and the signature:
    <m, enc(h(m))>
  - Decrypts the signature with..
    dec(enc(h(m))) == h(m)
  - Computes a message digest: h(m). Let's call it h'.
  - ..
    - If yes, then the message is authentic.
- Since only signer knows their private key,
  ..
  then they must have signed the document.

Trusting Unknown Companies

Digital Certificate

- Digital certificates use digital signatures.
- Scenario
  - Imagine sending password to website (e.g., Instagram).
  - You encrypt your password with Instagram's public key.
  - Only Instagram can decrypt the message, so password is safe.
- Questions
  - ..
  - One way:
    Instagram sends you their public key when you first go site.
  - How do you know if the public key really belongs to Instagram?
    But a rogue website could disguise as Instagram and send you a wrong key.

Secure Browsing

- HTTP has no encryption.
- HTTPS uses encryption:
  - Instagram sends you its public key in a digital certificate.
  - Digital Certificate:
    ..
  - Your OS verifies the authenticity of the digital certificate. OS has some built-in..
  - Your browser then uses Instagram's public key to encrypt messages to Instagram.
- Only Instagram can decrypt messages encrypted with their public key.

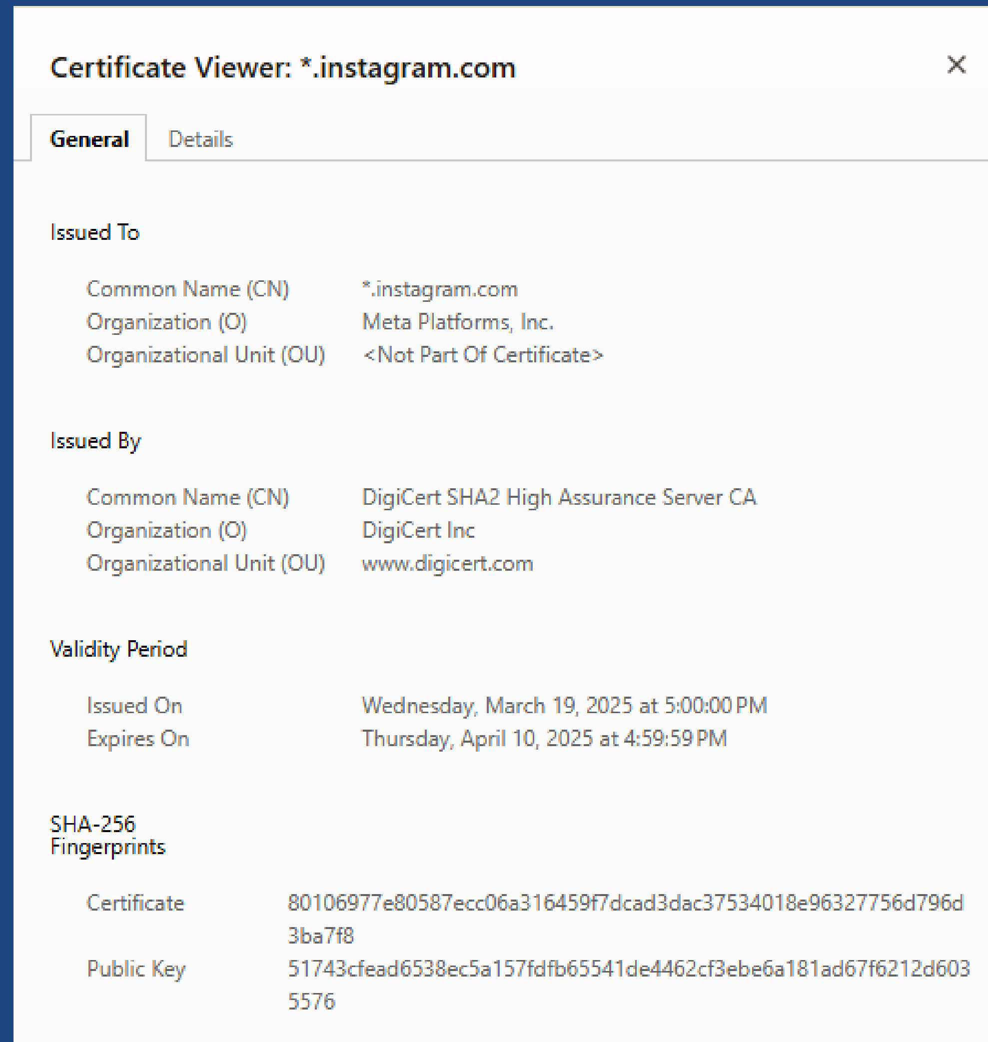
Digital Cert Operation

- How digital certificates work:
  - A digital certificate is signed by a digital certificate authority
    - E.g., VeriSign, DigiCert
  - OS vendor ships OS with public keys for some trusted digital certificate authorities like DigiCert.
    - This establishes the base level of trust:

      ..

Digital Certificate Example

- Instagram uses DigiCert:
  - Instagram goes to DigiCert, gives its public key, and requests a digital certificate.
- DigiCert creates a digital certificate:
  - It says "this public key belongs to Instagram"
  - ..



Digital Certificate Example (cont)

- Instagram Digital Certificate
  - When browser connects to Instagram, Instagram sends the digital certificate.
    - Browser uses its trusted public key for DigiCert to verify the digital certificate from Instagram.
  - If your OS is not compromised, this whole process is secure based on the first level of trust.
    - If the OS is compromised, there is no 1st level of trust and this whole process is not secure.
- Encryption Use
  - ..
    (public key is slow and generates lots of data)
  - Rest of communication..
    (faster, smaller)

Chain of Trust

- Digital certificates rely on the chain of trust
  - To trust the public key sent by Instagram, we need to trust DigiCert's signature.
  - To trust DigiCert's signature, we need to trust DigiCert's public key.
  - In order to trust DigiCert's public key (shipped with OS), we need to trust that our OS is not compromised.
- Chain of trust relies on the root of trust being trustworthy.
  - Our root of trust is the OS.

Activity: SSH

- [Opt] Spin up new container: docker run -it ghcr.io/sfu-cmpt-201/base
- Generate public/private key with ed25519 & passphrase
  `$ ssh-keygen -t ed25519 -C "your email address"`
  - Look at files in ~./ssh
- SSH SFU
  - ssh <yourID>@csil-cpu01.csil.sfu.ca -p24
    Asks user name & password; use VPN if off campus.
- SSH Keys
  - SSH SFU; manually add pub key to end of ~/.ssh/authorized_keys
  - Log-out, log-in (asks passphrase)
- SSH Agent: Avoids passphrase; Stores key in memory.

```
eval ssh-agent
ssh-add

kill $SSH_AGENT_PID
```

Hash Collisions

Birthday Match = Hash Collision

- Birthday Match
  - In a class of 30 people, probability of two students having the same birthday is..
    https://en.wikipedia.org/wiki/Birthday_attack
- Hash Collisions
  - Given enough messages,
    ..
  - i.e., can we show that a hash function
    ..
- (Recall) Strong collision resistance:
  It should be difficult to find two messages x and x' where h(x) == h(x').
  - i.e., given a hash function, it should be difficult to find two values that produce the same hash.

Birthday Attack

- Attacker use a contract the customer is expected to sign (say agreement to buy company for $100,000).
- Attacker then:
  - ..
    (adding a space, adding commas, adding typos, ...)
  - Creates malicious altered copies (sale price $100,000,000)
  - Goal: ..
  - Customer given benign copy to sign using their private key and hash of document.
  - Attacker then..
  - Since the contracts have same hash, attacker can claim customer signed malicious contract using their private key!

Demo: Hash Collision

- Demo: Collision in Crypto Hash Functions
  - MD5 was a widely used crypto hash function but was found to be insecure by 2005.
  - No longer in use.
- Get images & Compare Hashes

```
$ wget https://s3-eu-west-1.amazonaws.com/md5collisions/ship.jpg
$ wget https://s3-eu-west-1.amazonaws.com/md5collisions/plane.jpg
$ openssl dgst -md5 ship.jpg
$ openssl dgst -md5 plane.jpg
```

  - Algorithm exists to manipulate a pair of images into having the same MD5 hash.
- SHA255 is not yet known to be insecure.

```
$ openssl dgst -sha256 ship.jpg
$ openssl dgst -sha256 plane.jpg
```

ABCD: Birthday

- A birthday attack is successful when attackers find:

a) Two images that look the same but have different binary data.

b) Two students in CMPT 201 who have the same birthday.

c) A second document which matches the hash of a single given document.

d) Hash collision of a benign and malicious document.

Summary

- Passwords
  - Store salted and hashed passwords to avoid rainbow tables.
- Digest
  - A hash of a document.
- Digital Signatures
  - Sign a hash with a private key.
- Digital Certificates
  - Sign document to show who really owns a public/private key.
  - Chain of trust for distributing certificates.
  - Root of trust built into OS.
- Hash Collisions
  - Duplicate hash (digital signature) is a security issue.
  - Birthday attack to find duplicates.